



Standard Model at 13TeV with the CMS detector

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On behalf of the CMS Collaboration

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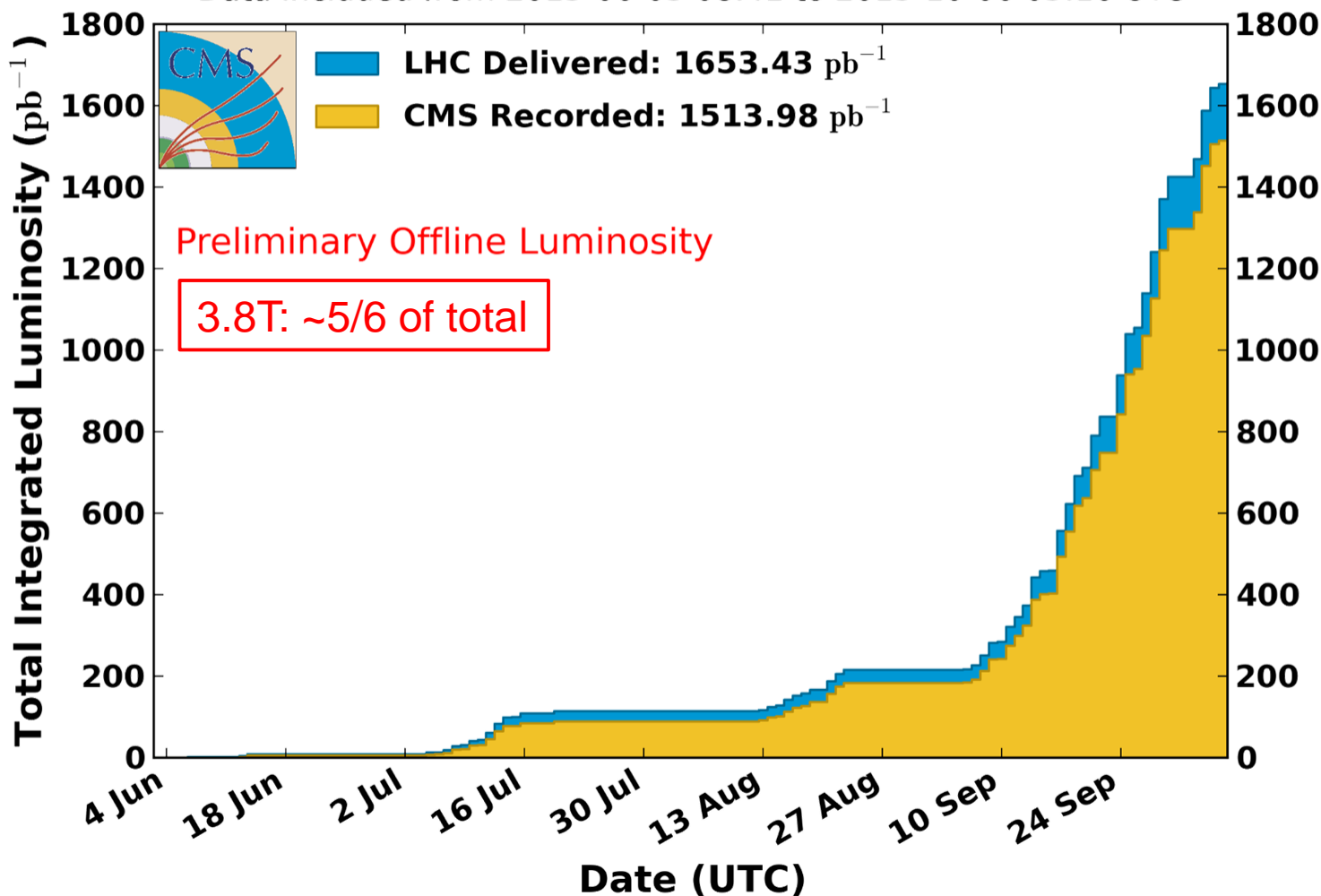
Executive Summary

- Run-2 quite a bumpy ride with CMS magnet
 - Enough 3.8T data for early searches and cross-section measurements; notable exception: di-boson physics
- First 13TeV results already presented at major conferences
 - Tracking and calorimetry performance
 - Charged-hadron multiplicity; top cross section
- CMS focus on completing 8TeV legacy papers
 - Completing preparations to fully exploit 13TeV sample when LHC ramps up
- SM results and prospects

Data Samples

CMS Integrated Luminosity, pp, 2015, $\sqrt{s} = 13$ TeV

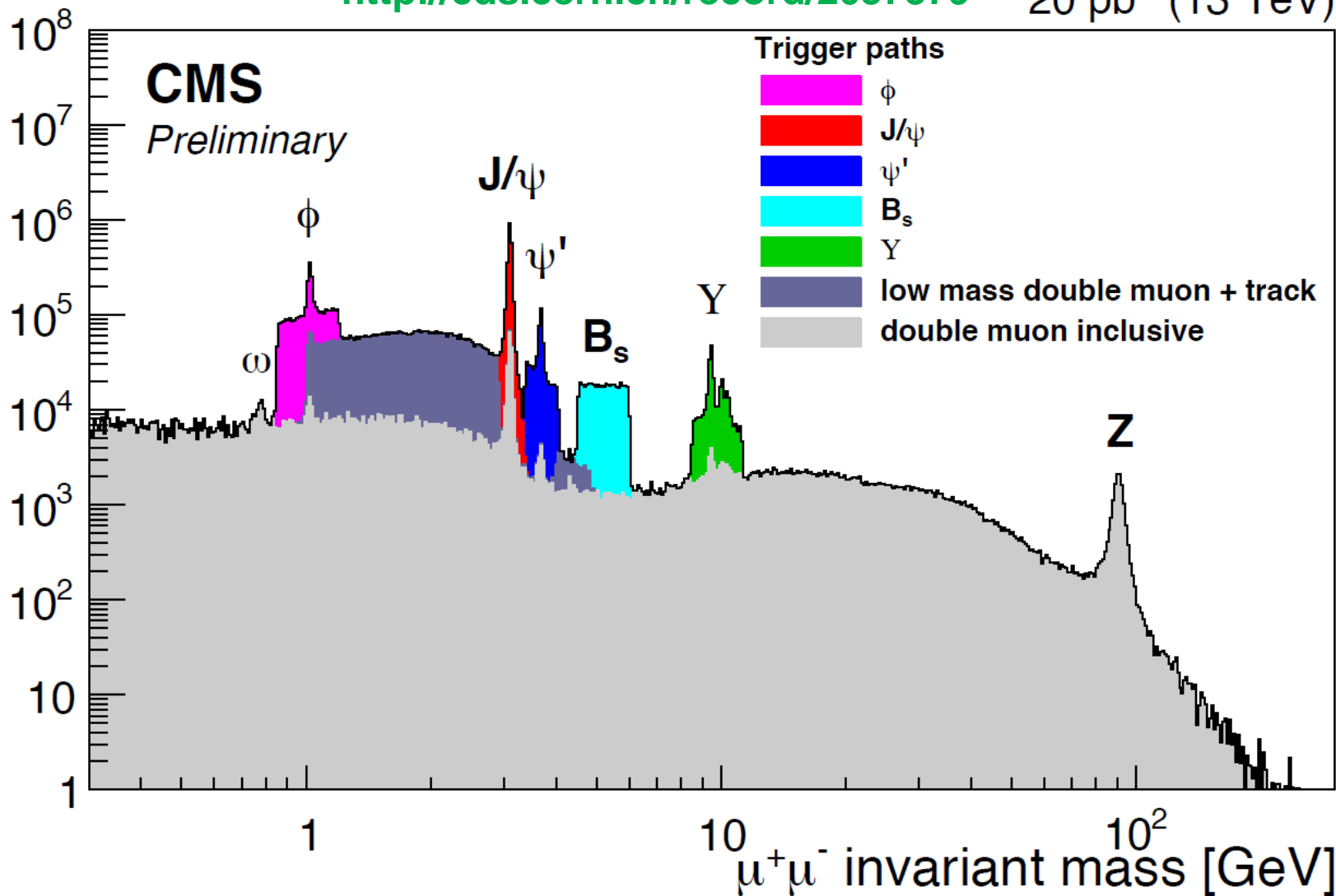
Data included from 2015-06-03 08:41 to 2015-10-06 05:16 UTC



Rediscovering SM...

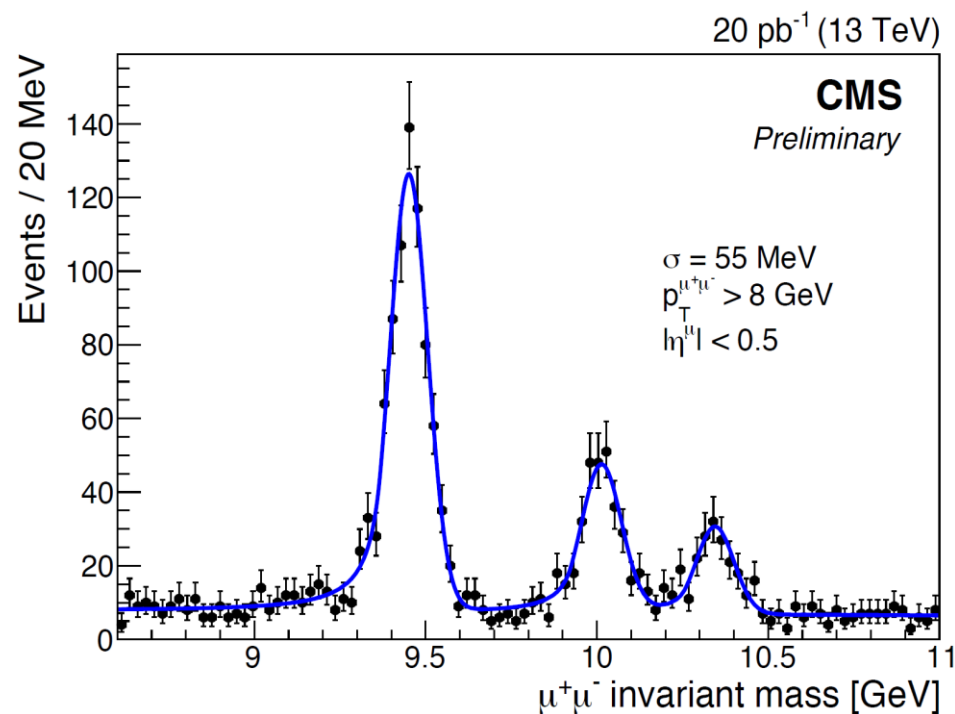
<http://cds.cern.ch/record/2037379>

20 pb⁻¹ (13 TeV)

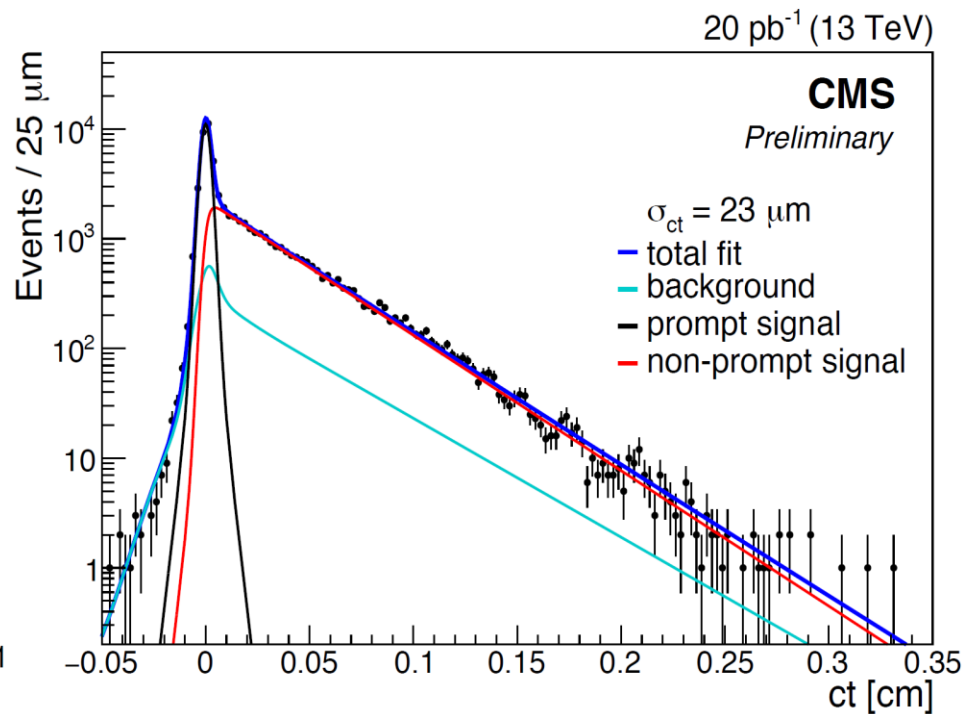


... more SM...

<http://cds.cern.ch/record/2037379>



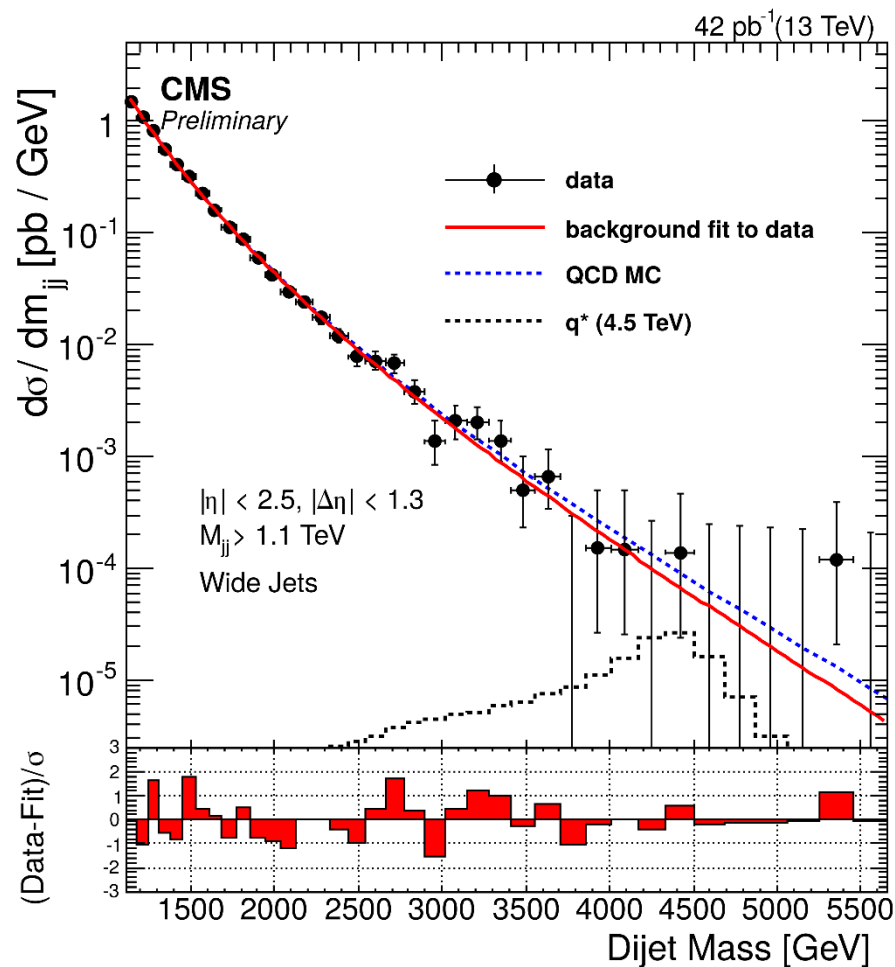
Zoom in $\Upsilon(nS)$ region



Proper decay length
 J/ψ candidates

...and going beyond

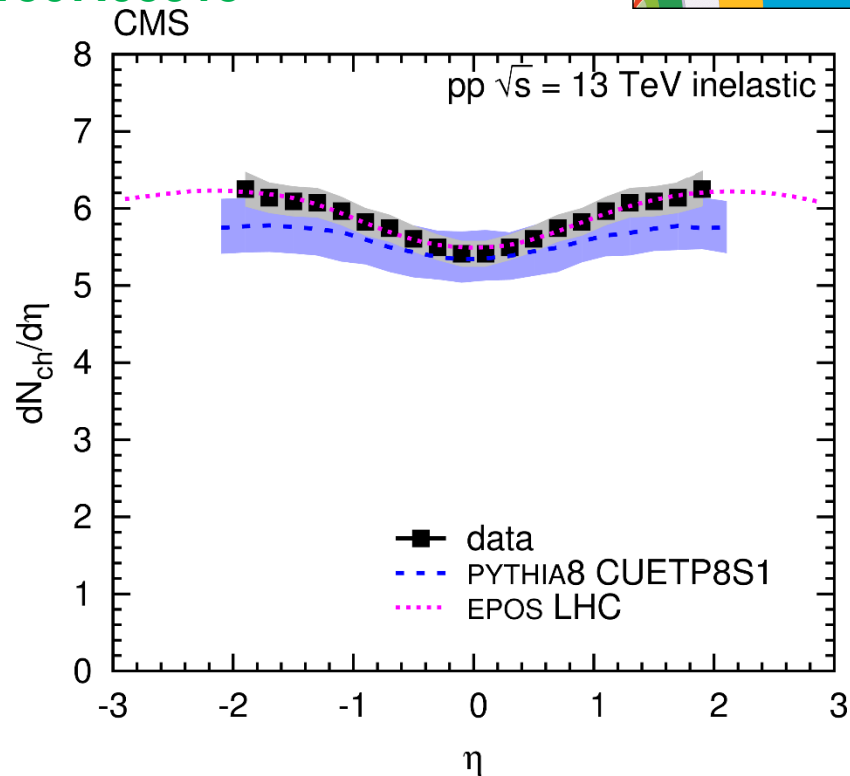
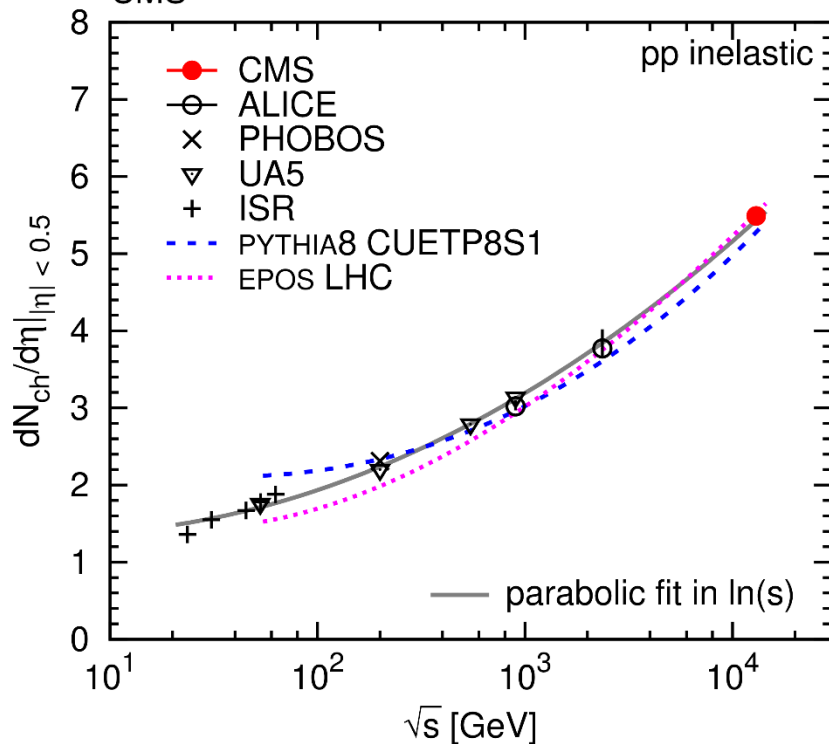
- Di-jet mass distribution fitted with 4-parameter function
- Superimposed $q^*(qg)$ signal with resonance mass 4.5 TeV
- 42/pb enough to exceed 8 TeV sample sensitivity for narrow resonances above 5 TeV



<https://cds.cern.ch/record/2048099>

Standard Model at 13TeV

<http://arxiv.org/abs/1507.05915>

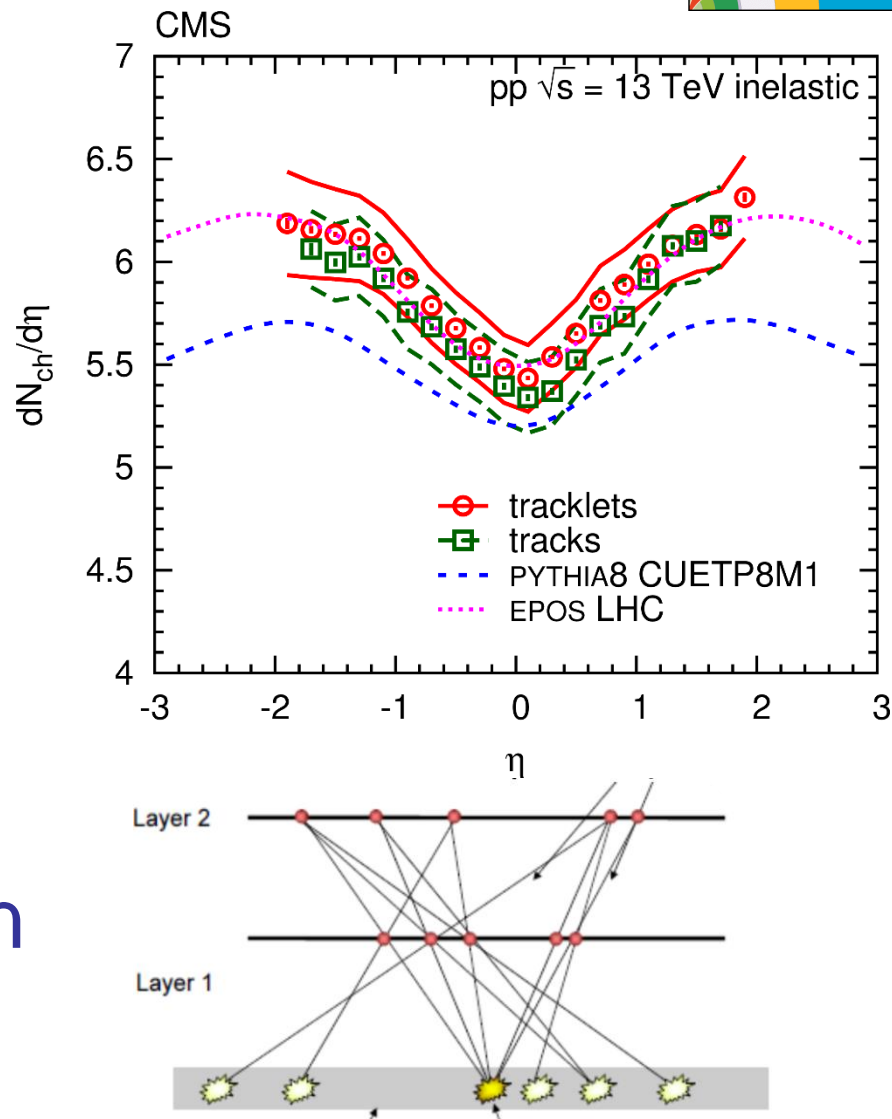


- Charged-hadron multiplicity and η -density
 - First 13TeV publication
 - Straight-track multiplicity: 0Tesla measurement
 - Crucial ingredient for tuning MC generators and pileup backgrounds

Cross-check with Tracklets



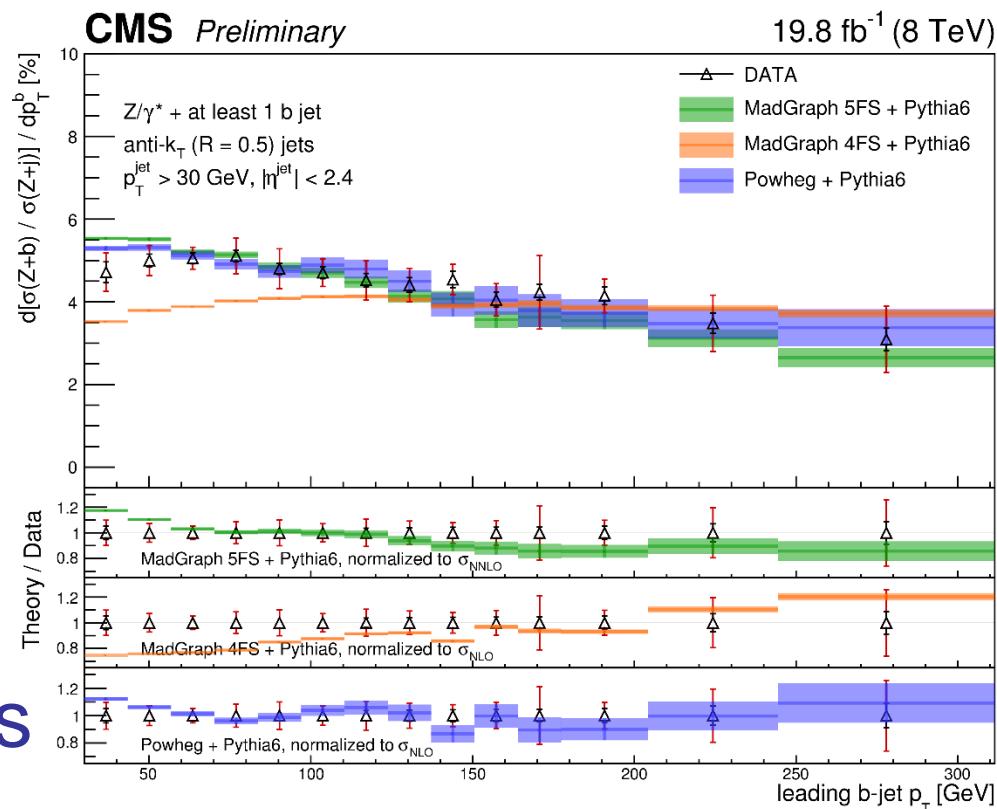
- Look for combination of pixel pairs in different layers
 - Sharp correlation in $\delta\eta$ and $\delta\phi$ for straight tracklets
 - Robust measurement, insensitive to alignment
- Consistent η -distribution with track-based result



Coming Up...



- **Vector bosons**
 - **W/Z inclusive cross section**
 - **Inclusive di-photon spectrum**
- **Vector bosons + jets**
 - **NNLO calculations available for Z+jets**
 - 1507.02850
- **Multi-boson final states**
 - **Coming a bit later, affected by small data sample**

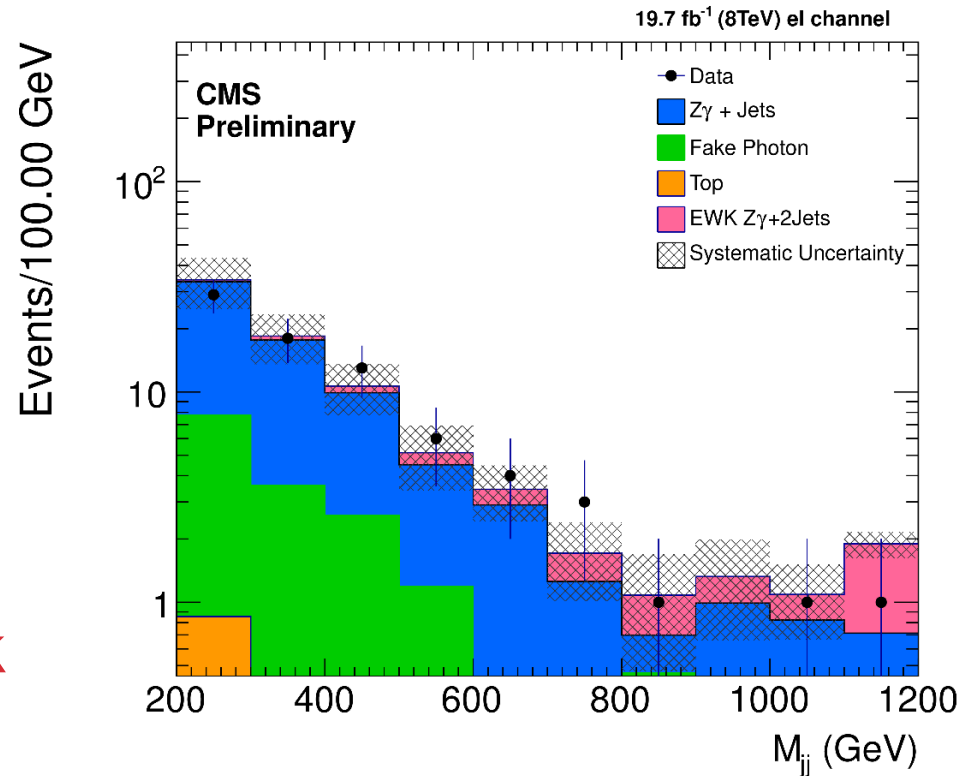


Z+b-jets (8TeV)

<https://cds.cern.ch/record/2044919>

Setting Final Words on 8TeV

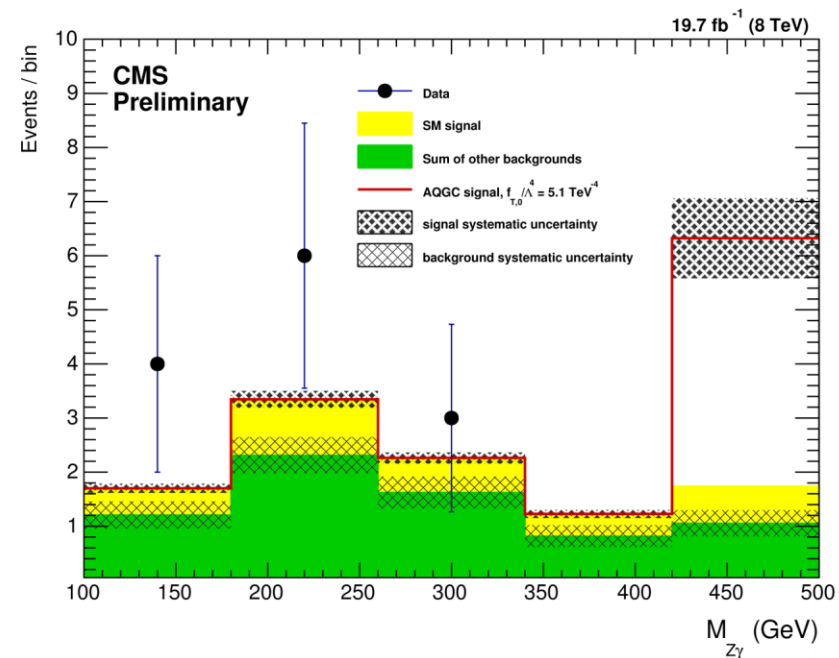
- Large effort dedicated to completion of 8TeV legacy papers
 - About 20 papers in last two years from SM group
- Latest result: $Z\gamma$ +jets
 - Evidence of electroweak production and limits on quartic gauge couplings



$Z\gamma$ +2-jets (8TeV)

<https://cds.cern.ch/record/2048148>

Electroweak $Z\gamma$ Production



August 2015		CMS	ATLAS	Channel	Limits	$\int L dt$	\sqrt{s}
f_{T0}/Λ^4				$W\gamma\gamma$	-9.0e+01 - 9.0e+01	20.3 fb ⁻¹	8 TeV
				$WV\gamma$	-2.5e+01 - 2.4e+01	19.3 fb ⁻¹	8 TeV
				EWK $Z\gamma+2\text{Jets}$	-3.8e+00 - 3.4e+00	19.7 fb ⁻¹	8 TeV
				ss WW	-4.2e+00 - 4.6e+00	19.4 fb ⁻¹	8 TeV
f_{T1}/Λ^4				EWK $Z\gamma+2\text{Jets}$	-4.4e+00 - 4.4e+00	19.7 fb ⁻¹	8 TeV
				ss WW	-2.1e+00 - 2.4e+00	19.4 fb ⁻¹	8 TeV
f_{T2}/Λ^4				EWK $Z\gamma+2\text{Jets}$	-9.9e+00 - 9.0e+00	19.7 fb ⁻¹	8 TeV
				ss WW	-5.9e+00 - 7.1e+00	19.4 fb ⁻¹	8 TeV
f_{T8}/Λ^4				EWK $Z\gamma+2\text{Jets}$	-1.8e+00 - 1.8e+00	19.7 fb ⁻¹	8 TeV
f_{T9}/Λ^4				EWK $Z\gamma+2\text{Jets}$	-4.0e+00 - 4.0e+00	19.7 fb ⁻¹	8 TeV

aQGC Limits at 95% CL (TeV⁻⁴)

- First measurement of electroweak $Z\gamma$ production
 - Cross section consistent with LO predictions
- Limits on aQGC competitive with other multi-boson channels
 - Dim-8 effective operators framework

ZZ Candidate at 13TeV



Run 251244 Event 204117665

$\sqrt{s} = 13 \text{ TeV}$

μ_1
 $p_T = 58.7 \text{ GeV}$
 $\eta = 1.8$

$pp \rightarrow ZZ \rightarrow 2e2\mu$

$m_{\mu\mu} = 91.1 \text{ GeV}$

$m_{ee} = 88.2 \text{ GeV}$

$m_{4\ell} = 208.9 \text{ GeV}$

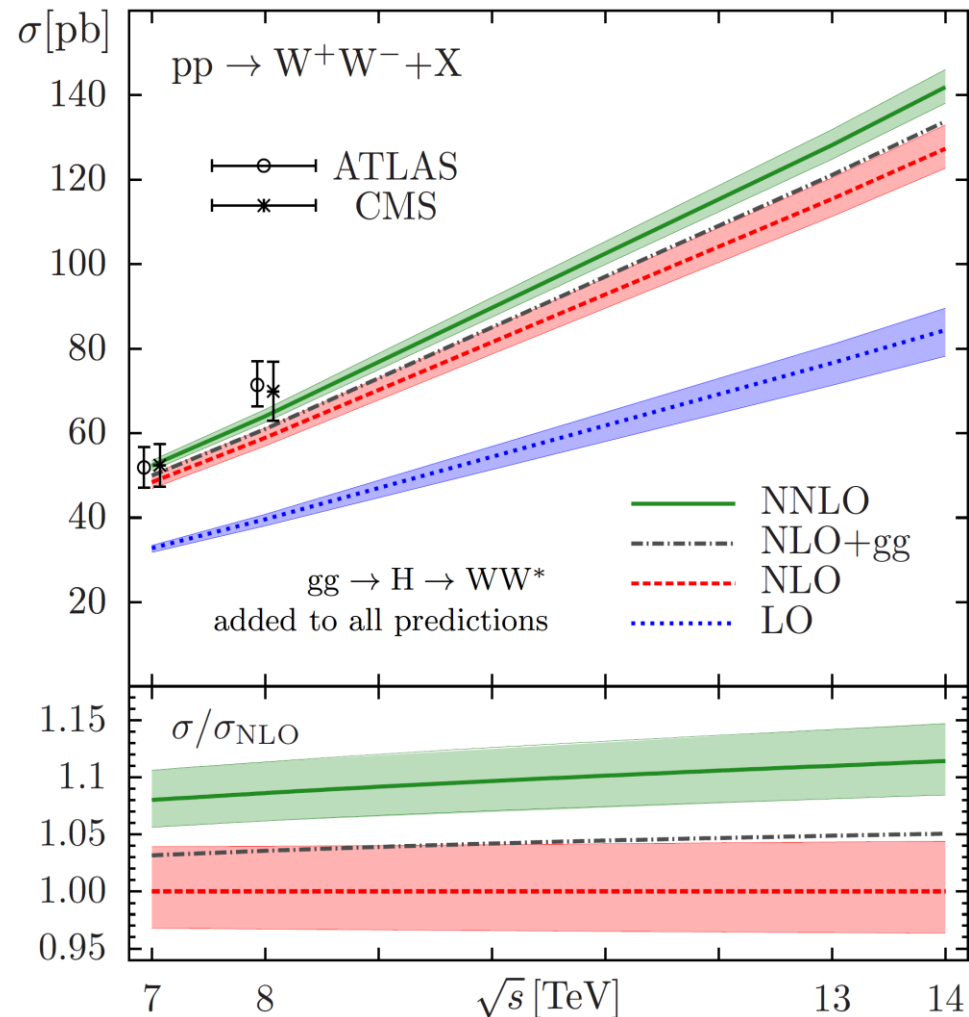
μ_2
 $p_T = 36.1 \text{ GeV}$
 $\eta = 0.98$

e_1
 $p_T = 63.3 \text{ GeV}$
 $\eta = 1.2$

e_2
 $p_T = 25.5 \text{ GeV}$
 $\eta = 0.20$

A few more on multi-boson

- NNLO precision now available for large number of processes
 - WW : 1408.5243
 - ZZ : 1507.06257
 - QCD N3LO: 1509.06734
 - $W\gamma, Z\gamma$: 1504.01330
- 5-10% increase w.r.t. NLO
 - Important for comparison to measurements
- Significance of higher-order corrections increase with center-of-mass energy



Conclusion

- The 13TeV SM program in CMS is shaping up
 - First measurements available, more soon to arrive
- Strong focus on legacy papers
 - Expect many high-precision papers on 8TeV data
- Appropriate resources devoted to preparation of 13TeV analyses requiring larger dataset
 - Multi-boson analyses ready for quick-start



Backup Material

The CMS Detector



CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel ($100 \times 150 \mu\text{m}$) $\sim 16\text{m}^2 \sim 66\text{M}$ channels
Microstrips ($80 \times 180 \mu\text{m}$) $\sim 200\text{m}^2 \sim 9.6\text{M}$ channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying $\sim 18,000\text{A}$

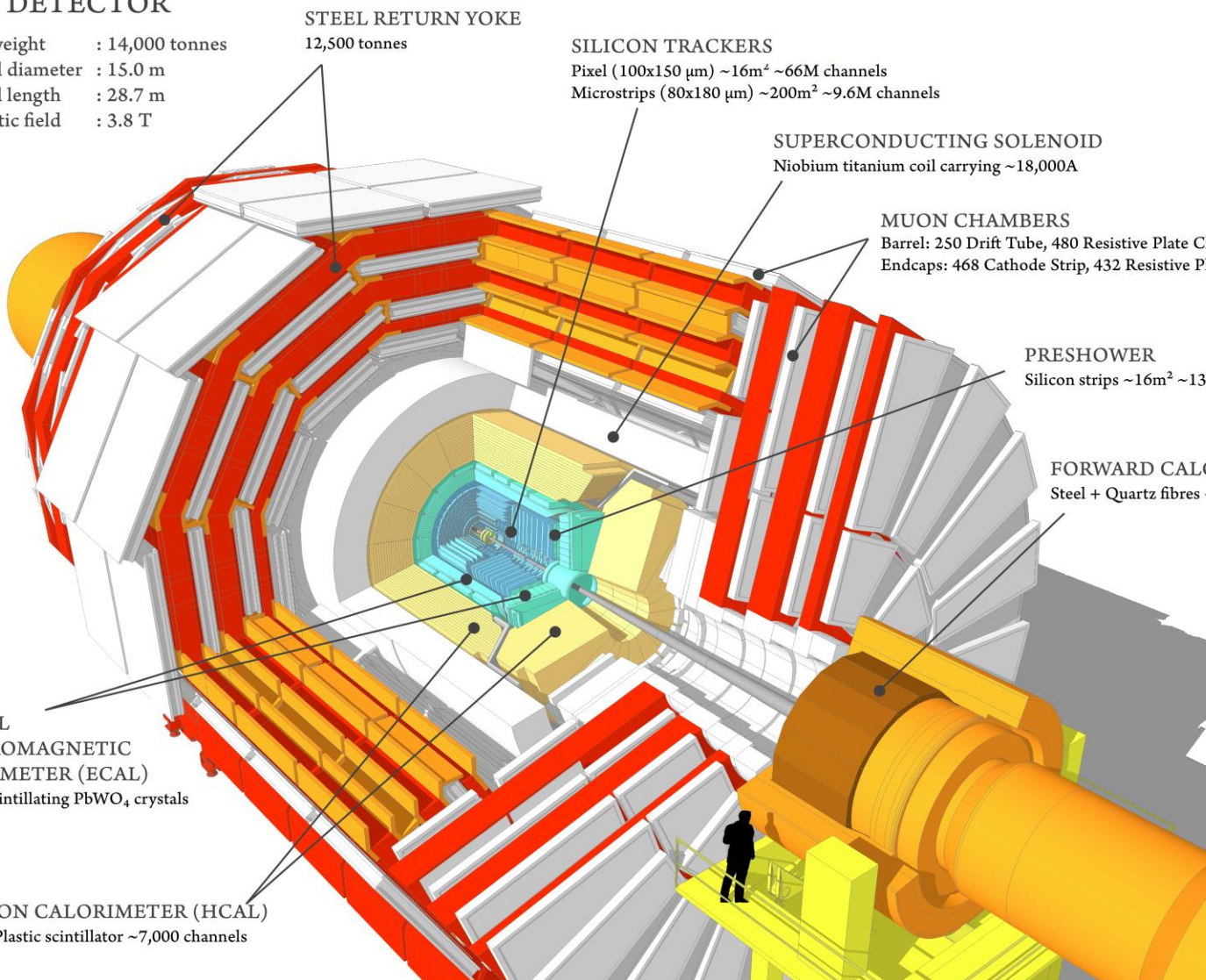
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

PRESHOWER
Silicon strips $\sim 16\text{m}^2 \sim 137,000$ channels

FORWARD CALORIMETER
Steel + Quartz fibres $\sim 2,000$ Channels

CRYSTAL
ELECTROMAGNETIC
CALORIMETER (ECAL)
 $\sim 76,000$ scintillating PbWO_4 crystals

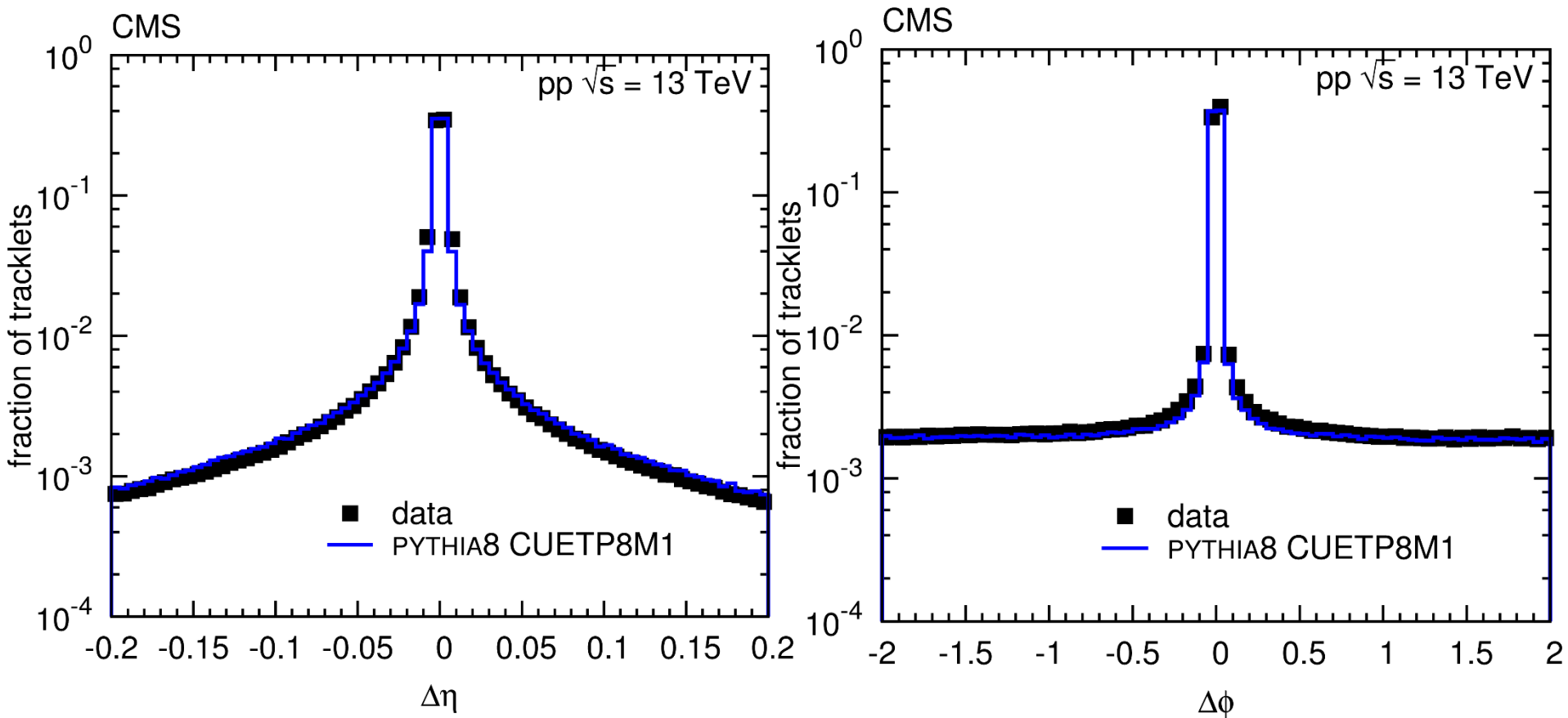
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator $\sim 7,000$ channels



The Magnet Story

- The restart of the CMS magnet after LS1 was more complicated than anticipated due to problems with the cryogenic system in providing liquid Helium
- Inefficiencies of the oil separation system of the compressors for the warm Helium required several interventions and delayed the start of routine operation of the cryogenic system
- Currently the magnet can be operated, but the continuous up-time is still limited by the performance of the cryogenic system requiring more frequent maintenance than usual
- A comprehensive program to re-establish its nominal performance is underway. These recovery activities for the cryogenic system will be synchronized with the accelerator schedule in order to run for adequately long periods
- A consolidation and repair program is being organized for the next short technical stops and the long TS at the end of the year

Pixel Layer Correlations



$\delta\eta$ and $\delta\phi$ distributions of hit pairs on tracklets